Screening-Level Human Health Risk Assessment for Kettle Creek, Port Stanley – PAH Contaminated Sediment

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For more information:
call 416-325-4000 or toll free 1-800-565-4923
picemail.moe@ontario.ca
www.Ontario.ca/Environment

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Screening-Level Human Health Risk Assessment for Kettle Creek, Port Stanley - PAH Contaminated Sediment

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Executive Summary

Elevated levels of polycyclic aromatic hydrocarbons (PAHs) from past industrial activity have been found in some sediments of Kettle Creek in Port Stanley, in an area where runoff from an industrial site meets the creek, referred to in this report as the Kettle Creek area of concern (KAC). Additionally, elevated levels of PAHs have been detected in the George St. Drain (Drain), an area that received runoff from the industrial area, which flows into Kettle Creek. Although limited human exposure to sediments from the KAC and the Drain is anticipated, the Ontario Ministry of the Environment (the Ministry) carried out a Screening-Level Human Health Risk Assessment (SL-HHRA) to estimate the risk to human health if a person fell into the water when boating or deliberately entered into the Drain area. In carrying out the SL-HHRA, the Ministry used recognized risk assessment methodologies and conservative assumptions regarding the potential for human exposure to the contaminated sediment. The PAH concentration data were obtained from sediment sampling conducted by the Ministry in 2009.

Some PAHs, such as benzo[a]pyrene (B[a]P), are carcinogens. Cancer from long-term exposure to PAHs represents a sensitive adverse health effect that can be considered in a screening-level risk assessment. The Ministry sets standards and guidelines for non-threshold carcinogens based on a target cancer risk level (CRL) of one in a million ($1x10^{-6}$) excess cancers. When a target risk level is exceeded, risk mitigation and management measures are considered to reduce the risk below the target level. Additionally, while cancer was the main concern, the Ministry also thought it prudent to examine the potential risk of non-cancer health effects.

The Ministry assessed risk from four different theoretical exposure scenarios for the KAC and one scenario for the Drain. The exposure scenarios included both five and 12 exposures per year and are summarized as follows:

1) KAC: Worst-case scenario assessing exposure using the maximum total PAH concentration reported in the surface sediments and assessing toxicity assuming the entire sample was B[a]P (the PAH of most toxicological concern);

2) KAC: Same as Scenario 1 but with the toxicity of the maximum total PAH concentration, reported in the surface sediments, assessed using B[a]P equivalents (i.e., accounting for the toxicity of the individual PAH compounds present);

3) KAC: Same as Scenario 2 but accounted for the range of sediment depths from which samples were collected that included but were not limited to the surface layer

(i.e., at least a portion of each sediment sample collected was from within the upper 10cm).

4) KAC: Most realistic scenario of the 4 scenarios considered for the KAC (exposure 5 or 12 times per year from birth to age 76) taking the average PAH concentration, as B[a]P equivalents, from all sediment samples where the depth included at least a portion of the upper 10cm.

5) Drain: Scenario 5 examined potential risk from exposure in the Drain using the same methodological approach in calculating average B[a]P equivalents as Scenario 4.

The maximum risk posed in the worst-case scenario (Scenario 1), as indicated by the CRL, was 6 in 100,000 for 12 events per year with lower risks estimated in all other scenarios the Ministry considered to be more realistic. In the most realistic exposure scenario for Kettle Creek (Scenario 4) the CRL was below the Ministry's target CRL for 5 events per year and equivalent to the target CRL of 1 in 1,000,000 for 12 events per year. Scenario 4 is the most relevant for estimating risk as it incorporates data from all locations assessed whereas the risks estimated in the other scenarios were based on specific sampling locations. The approach used in Scenario 4 is reasonable as it is unlikely that sediments suspended in the water column are stagnant. Rather, they are moving and being mixed and, therefore, an individual's exposure is not based on any one sampling point, but rather a composite of all. Further, water depth above the sampling stations is very shallow and so it is extremely unlikely that a boat would have access to these areas and therefore unlikely that an individual would fall into the water at these locations. Accidental exposure is more likely to occur as a result of falling or jumping off a boat in the deeper part of the river channel where any sediment exposure would be to sediments mixed into the water column. As a result Scenario 4 assumes equal mixing of all stations assessed has occurred.

In Scenario 5 (the Drain) the highest CRL was calculated to be 3 in 100,000, for 12 events per year. Since the CRL is above the Ministry's target CRL, consideration may be given to risk management and mitigation measures. However, the conservative assumptions used in the exposure assessment may have resulted in an over-estimation of the risk in the Drain. Also of note is that exposure at this location would be as a result of trespassing on private property.

In the examination of potential risk for chronic non-cancer health effects to result from exposure at both the KAC and the Drain, HQs were calculated and compared to the Ministry's target of 0.2 for several of the PAH congeners as well as for the sum of the individual HQ's. All HQ's were several orders of magnitude below the target risk level indicating that the risk of chronic non-cancer health effects at this site is negligible.

Introduction

Elevated levels of polycyclic aromatic hydrocarbons (PAHs) from past industrial activity have been found in some sediments of Kettle Creek in Port Stanley, in an area where runoff from an industrial site meets the creek, referred to in this report as the Kettle Creek area of concern (KAC). Although limited human exposure is anticipated to sediments from the KAC, the Ministry carried out a Screening-Level Human Health Risk Assessment (SL-HHRA) to estimate the risk to human health if a person fell into the water when boating in the KAC. Due to the physical characteristics of this part of the Creek the assumption was made that swimming would not occur in this area. In addition the Ministry also estimated risk to human health from sediments in the Drain, an area which receives runoff from industrial land, which had been contaminated with PAHs, and flows into Kettle Creek. This report summarizes the assumptions and results of the SL-HHRA carried out.

Background

As reported by the Ministry in its April 2010 Report: *Delineation of Polycyclic Aromatic Hydrocarbons (PAHs) in the Sediments of Kettle Creek at Port Stanley, Ontario* (the Report), PAH contamination of the land and sediment in the vicinity of the KAC and the Drain occurred as a result of industrial activities. The Ministry undertook sampling of this area in the mid-1980's and subsequent clean-up actions on a nearby industrial site ensued for the purposes of source control. In 2009 further sampling was undertaken by the Ministry to delineate the current horizontal and vertical extent of PAHs in the sediments of Kettle Creek within the KAC and Drain. Concern for potential human exposure in this area was identified as there are marinas located on the east side of Kettle Creek in the vicinity of where contaminated sediment samples had been collected and boat docking facilities upstream. The marinas are located along the shore directly opposite the area in which PAH contaminated sediments were collected. The distance between the two shores ranges from approximately 50 – 70m. Recreational boating activities in this area have the potential to result in human contact with contaminated sediments as a result of either falling or jumping out of a boat into the water. In addition to boating activities Ministry staff noted that while the Drain is on private property there are 'additional boat slips and a parking area' adjacent to the private property that the Drain is located on and as a result risk was also assessed for the potential contact with contaminated sediments at the Drain.

Problem Formulation

Sediment in this area has been found to contain PAHs and is, therefore, the medium of concern. This SL-HHRA assessed two potential exposure pathway scenarios which could result from contact with sediment while in the water as a result of recreational boating in Kettle Creek or trespassing in the Drain. Near shore wading was not

assessed because the shoreline is entirely on private property. In order for the sediment to pose a risk to human health, an individual must come into contact with the contaminated sediment. For this to happen, the sediments must become mixed into the water column (resuspended). Due to the proximity of marinas and boat slips to the KAC the Ministry considered that it is plausible that recreational boaters may come into contact with contaminated sediment as a result of falling or jumping out of a boat. It was determined that the two exposure routes that could occur in this scenario were incidental ingestion and dermal absorption of sediment resuspended in the water column. Since cancer is the outcome of concern from exposure to PAHs risk was calculated for the composite receptor. A composite receptor considers that an individual is exposed to a carcinogen throughout their life – that is the life stages of infant, toddler, child, teen and adult – and assesses risk by determining a time-weighted exposure. A pregnant female receptor may be more sensitive to certain compounds and this increased susceptibility can be accounted for by adjusting the adult receptor weight in the dose calculations used to determine risk. Where that is done in this SL-HHRA it is indicated by stating the receptor is a composite female receptor.

The Drain – while the area surrounding the Drain is private property the Ministry recognizes that it is easily accessible from heavily used boat slips and a parking area. Therefore, the potential for trespassing individuals to come into contact with the sediment at this location was identified. Playing in the Drain was the identified exposure pathway of concern that could result in both dermal contact and incidental ingestion.

Compounds of Concern

PAHs encompass a large class of organic compounds that contain only carbon and hydrogen and are comprised of two or more fused aromatic rings. They occur as complex mixtures, not as single compounds, are formed as a result of incomplete combustion of organic material and are found in air, water, food, soil and sediment. PAHs in the aquatic environment tend to accumulate in sediment since they have low water solubility and high affinity for lipids (high octanol-water partition coefficients). Therefore, the SL-HHRA focused on exposure to sediment.

Health and environmental agencies are mainly focused on protecting humans against potential health effects from long-term exposure to PAHs, specifically cancer. This is because various agencies, including the International Agency for Research on Cancer (IARC), have classified some of the individual PAH congeners as carcinogenic to humans (Group 1), probable (Group 2A) or possible (Group 2B) human carcinogens. In IARC monograph 92, published in 2010, benzo[a]pyrene has been classified as a Group 1 carcinogen and is therefore considered by that agency to be carcinogenic to humans. Some of the PAH congeners have been found to cause tumours in laboratory animals. Human studies have also reported cancers as a result of prolonged inhalation or dermal exposure. Non-cancer health effects from long-term exposure include effects on the nervous system and liver.

Data on human health effects following acute exposure to PAHs is extremely limited. However, depending upon the route of exposure, skin and gastrointestinal irritation have been reported. These acute effects have been reported after exposure to high levels of PAH mixtures not normally found in the environment. Due to the limited data, toxicity reference values, used in determining the magnitude of potential risk, have not been derived for acute exposure to PAHs. As a result, acute exposures were not assessed in this SL-HHRA.

Appendix 4 of the Report provides concentration data for 18 PAH congeners monitored in 2009. Toxicity equivalency factors (TEFs) have been developed for 13 of these congeners. When available, the Ministry routinely uses TEFs in risk assessments as they allow for a more realistic characterization of risk. The TEF approach is a comparison of adverse effects between an individual PAH congener and benzo[a]pyrene, to develop a toxicity equivalency value for a specific PAH congener with respect to B[a]P. There is a variety of TEF sets available, developed by different researchers and agencies. In conducting risk assessments the Ministry has used the TEF set adopted by the World Health Organization which was developed by Kalberlah *et al.,* (1995). The 13 PAHs for which TEFs were used in this SL-HHRA are: acenaphthylene, acenaphthene, anthracene, fluoranthene, pyrene, benzo[a]anthracene, chrysene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, ideno[1,2,3-c,d]pyrene, dibenzo[a,h]anthracene, benzo[g,h,i]perylene. Of those benzo[a]pyrene and dibenzo[a,h]anthracene are the most potent.

Exposure Assessment

A key step in calculating potential risk is determining the concentration of the contaminant, in this case PAHs, to which an individual is exposed. Sediment sampling and PAH analysis was conducted for both surface and subsurface sediments in 2009. The sampling data was reviewed and only those samples that are currently located under water and include at least a portion of the first 10 cm of sediment were included in this assessment. It was assumed that sediment located deeper than 10 cm would be unlikely to mix into the water column. However, because core sample depth was not consistent, there were several cases in which the concentrations of sediments located below the first 10 cm were included. The deepest sample is Station 10-28 which included sediments at a depth of 7.5 to 33 cm. The PAH and B[a]P equivalent concentrations used in the calculations are provided in each scenario assessed. Details, equations and assumptions used in the dose calculations are also provided.

In calculating CRLs it was decided that if the Ministry's risk targets were exceeded, the assumptions used to calculate the dose, and associated risk would be refined, to provide a more realistic risk estimate. The use of the TEF approach was the method selected to refine dose estimates and associated risk calculations. Refined risk calculations were undertaken for Stations 5-4 and 5-10. Station 5-10 was selected because upon examination of individual PAH concentration data it was noted that 5-10

reported the highest concentration of B[a]P and B[a]P equivalents. B[a]P was singled out as it is one of the most potent PAHs.

The Drain: In September 2009 a sediment sample was taken at the Drain and the concentrations of 18 PAH congeners were determined for 3 depths (ranging from 0 to 30 cm). In calculating the risk for the Drain the Ministry calculated the average concentration for each of the 13 PAH congeners, for which TEFs have been developed, converted them to B[a]P equivalents and summed them to get the total B[a]P equivalents which was used to calculate the risk.

Pathways and Receptors

Two exposure pathways were identified to be of potential concern for exposure to the public. These were contact with contaminated sediment as a result of falling or jumping into the water during boating activities and contact with contaminated sediment in the Drain as a result of trespassing and playing in the Drain. Cancer risk levels were calculated for the composite receptor as well as for the composite female receptor. Exposure could result as it is presumed that PAHs adsorbed to sediment particulate would adhere to the skin of a receptor following dermal contact. The exposure routes assessed, whereby the receptor would actually take the contaminant into their body, were:

1. Falling or jumping into the water while boating: incidental ingestion and dermal contact with resuspended sediment in the water column; and
2. Playing in the Drain: incidental ingestion of sediment as a result of hand-to-mouth activities and dermal contact with the sediment.

Exposure Frequency (EF)

Assumptions regarding exposure frequency are required to calculate a dose. Dermal contact with sediment, resuspended in the water column, can only occur if a person enters the water in the area of concern. It is an event driven exposure and is a function of the number of days per year that this 'incident' occurs. Two exposure frequencies were assessed and incremental cancer risk levels were calculated for them, these were:

1. Five (5) exposure events per year; and
2. Twelve (12) exposure events per year based on the assumption that exposure occurs three times for each month from May to August inclusive.

Exposure Parameters

Unless otherwise indicated the values for all parameters and variables were taken from the 2009 *Rationale for the Development and Application of Generic Soil, Groundwater, and Sediment Criteria for use at Contaminated Sites in Ontario* and are provided in Tables 1 and 2.

Table 1

Receptor Characteristics							
Receptor (age range)	ED (years)	AT (days)	BW (kg)	SA (cm^2)[a] KAC	SA (cm^2)[b] Drain	SIR (kg/d)	SAF ($kg/cm^2/d$)
Infant (0 – 6 mo)	0.5	182.5	8.2	2305	1300	$3*10^{-5}$	$7*10^{-8}$
Toddler (6 mo – 4 yrs)	4.5	1642.5	16.5	3885	2150	$2*10^{-4}$	$2*10^{-7}$
Child (5 – 11)	7	2555	32.9	6600	3585	$5*10^{-5}$	$2*10^{-7}$
Teen (12 – 19)	8	2920	59.7	10195	5480	$5*10^{-5}$	$7*10^{-8}$
[c]Adult (20^+)	56	20440	70.7	11550	6190	$5*10^{-5}$	$7*10^{-8}$
[c]Adult Female (20^+)	56	20440	63.1	10745	5780	$5*10^{-5}$	$7*10^{-8}$

[a] SA assessed arms, hands, legs, feet and head; the torso was not included.
[b] SA assessed forearms, hands, lower legs and feet.
[c] Note: To avoid double counting of the adult receptor only one of these receptors is carried through the calculations to determine the incremental cancer risk level (ICRL).

Table 2

Exposure Parameters	
Variable	Value
B[a]P OSF $(mg/kg/d)^{-1}$	7.3
ABS (unitless)	0.13
OAF (unitless)	1
*EF number of events per 365 days	5 or 12
CF days per year	365
AP (days)	27740

*EF – separate analyses were conducted for 5 events per year and 12 events per year

Definition of Receptor Characteristics and Exposure Parameters:

ABS – skin absorption factor (unitless)
AP – lifetime averaging period (days)
AT – averaging time (days)
[B(a)P] – concentration of B(a)P in sediment mg/kg
$[B(a)P]_{eqv}$ - concentration of B(a)P equivalents in sediment mg/kg (calculated using TEFs)
B[a]P OSF – oral slope factor for benzo[a]pyrene $(mg/kg/d)^{-1}$
BW – body weight (kg)
ED – exposure duration (years)
EF – exposure frequency (number of events per 365 days)
CF – conversion factor (365 days per year)
OAF – oral absorption factor (unitless)
SA – total skin surface area (cm^2) see Table 1 for the body parts included in each analysis
SAF – soil adherence factor ($kg/cm^2/d$)
SIR – amount of ingested sediment (kg/d)

Exposure Assumptions

Several iterations of calculations were carried out, using different sediment concentrations of PAH congeners and the corresponding B[a]P equivalents to determine the associated risk. Initially a high end worst-case exposure scenario was assessed. As that scenario resulted in risk levels which exceeded the ministry's target CRL further refining of sediment concentrations were conducted. The results of each iteration, associated assumptions, calculations and cancer risk levels are presented in the sections which follow.

Dose Equations

Incidental ingestion of sediment: The absorbed intake ($I_{ing\text{-}sed}$) or dose per event resulting from incidental ingestion of sediment can be estimated using the following equation:

$$I_{ing\text{-}sed} = [[(SIR * ED)/BW] * EF * CF * [B(a)P]_{eqv} * OAF] / AP$$

Dermal contact with sediment: The absorbed intake ($I_{der\text{-}sed}$) or dose per event resulting from dermal contact with sediment can be estimated using the following equation:

$$I_{der\text{-}sed} = [[(SA * SAF * ED)/BW] * EF * CF * ABS * [B(a)P]_{eqv}] / AP$$

CRLs

CRLs were calculated by summing the dose estimates for each receptor lifestage and then multiplying by the oral slope factor for benzo[a]pyrene.

$$CRL_{ing\text{-}sed} = \sum(I_{ing\text{-}sed})_{receptor} * OSF$$

$$CRL_{der\text{-}sed} = \sum(I_{der\text{-}sed})_{receptor} * OSF$$

$$\text{Total ICRL} = (\sum(I_{ing\text{-}sed})_{receptor} + \sum(I_{der\text{-}sed})_{receptor}) * OSF$$

Risk Characterization

Scenario 1: Worst-case Assumptions

Initially the Ministry conducted a preliminary risk assessment taking a very conservative approach to determine if a 'worst-case' scenario would indicate that risk existed at this site. This involved calculating the cancer risk for the Station which reported the highest total PAH concentration in surface sediments. From an examination of Appendix 5 (2009 surficial sediment depths and total PAH concentrations) of the Report it was determined that Station 5-4 (depth of 0 – 7 cm) had the highest Total PAH concentration at 66.5 ug/g. In a further conservative assumption the risk was calculated assuming the entire sample was benzo[a]pyrene (eg., benzo[a]pyrene equivalents were not calculated for each of the PAH congeners).

The resulting CRLs exceeded the Ministry's target for both the composite receptor and composite female receptor for both 5 and 12 events per year. For 5 events per year the total CRL was approximately 2 in a hundred thousand for both the composite adult and composite female adult. For 12 events per year the risk was approximately 6 in a hundred thousand for both the composite receptor and the composite female receptor. The CRLs were above the one in a million target for both routes of exposure (incidental ingestion and dermal exposure).

As the majority of the assumptions used in the above assessment were conservative and because the Ministry`s risk targets were exceeded a more refined analysis with the data provided was conducted. See 2nd scenario.

Use of B[a]P Equivalents

Scenario 2: Station 5-4 B[a]P Equivalents

Assuming that the total PAH concentration identified in Scenario One was comprised solely of benzo[a]pyrene was an overly conservative approach. In reality PAHs in the environment occur as a complex mixture of the PAH congeners. As the *Report* provided concentration information for 18 individual PAHs, the next step was to calculate B[a]P equivalents using the TEFs developed by Kalberlah *et al.,* 1995. B[a]P equivalents of 8.6 ug/g were calculated for Station 5-4.

In this scenario the resulting CRLs exceeded the Ministry's target for both the composite receptor and composite female receptor for both 5 and 12 events per year. For 5 events per year the total CRL was approximately 3 in a million for both the composite receptor and the composite female receptor. For 12 events per year the risk ranged from approximately 7 in a million for the composite receptor to 8 in a million for the composite female receptor. All CRLs were at or above the one in a million target for both routes of exposure.

Scenario 3: Station 5-10 B[a]P Equivalents

In reviewing the PAH concentration data for all stations reporting samples which encompassed at least a portion of the first 10 cm of the sediment it was noted that total PAH concentration was highest at Station 5-10 and the concentration of some of the PAH congeners was highest at Station 8-10. As a result the Ministry determined that it was appropriate to calculate risk levels based on B[a]P equivalents for these two stations. B[a]P equivalents were calculated to be 14.9 ug/g and 13.2 ug/g for Stations 5-10 and 8-10 respectively. As B[a]P equivalents were highest at Station 5-10 CRLs were calculated for that Station only.

In this scenario the resulting CRLs exceeded the Ministry's target for both the composite receptor and composite female receptor for both 5 and 12 events per year. For 5 events per year the total CRL was approximately 5 in a million for the composite receptor and 6 in a million for the composite female receptor. For 12 events per year the risk was approximately one in a hundred thousand for both the composite receptor and the composite female receptor. All CRLs were above the one in a million target for both routes of exposure.

Scenario 4: Average B[a]P Equivalents for Surface Sediment Samples

Further refining of the exposure scenarios involved deciding what would be a reasonable exposure scenario. Since water depth above the sampling stations assessed in this report is very shallow it is highly unlikely that an individual would be present at any one of these points. It was determined that a more reasonable exposure scenario would be for accidental exposure as a result of falling from a boat in the deeper part of the river, away from the stations sampled. The resulting potential exposure would be to surface sediments resuspended in the water column and so assessing the 'average' of the PAH concentration was determined to be a more realistic approach to use in calculating potential risk. The assumption behind this approach was that the water in the river would be flowing, and therefore mixing, and as a result an individual's potential exposure would be best represented not by the concentration at any one individual sampling station but by an average of all the surface sediment concentrations. It was decided that any station whose depth included at least a portion of the top 10 cm of sediment would be included in this analysis. This resulted in the identification of 44 different concentrations for each PAH congener, representing 26 distinct sampling locations, for each of the 13 individual PAH congeners. The average concentration of each of the 13 PAH congeners was calculated and then converted to a B[a]P equivalent. The 13 B[a]P equivalents were then summed to provide the total average B[a]P equivalents (1.65 ug/g) which was used to calculate the CRL for the KAC.

In conducting this analysis the total cancer risk level was below the risk target for both receptors in the 5 events per year scenario. While for 12 events per year the individual routes of incidental ingestion and dermal exposure were below the target risk level but

the combined, total cancer risk level was equal to the one in a million target level for both receptors.

Scenario 5: The George Street Drain

The Ministry also had some concerns with exposure at the Drain. In September 2009 sediment samples were collected at 3 depths at the Drain. The approach used in Scenario Four to calculate the exposure concentration was also used for the Drain. That is, the average concentration for each of the 13 PAH congeners, for which TEFs are available, was calculated and then converted to a B[a]P equivalent. Benzo[a]pyrene equivalents were then summed to provide the total average B[a]P equivalents for the Drain.

Assumptions regarding the exposure scenario at the Drain were:

a) Incidental ingestion of sediment would occur as a result of hand-to-mouth activity from 'playing' in the water and soil/sediments in and around the Drain; and
b) Dermal absorption of sediment from contact with the skin while in the water and soil/sediments in and around the Drain.

The resulting CRLs exceeded the Ministry's target for all exposure routes and receptors. For 5 events per year the risk was 1 in a hundred thousand for both the composite receptor and the composite female receptor. For 12 events per year the total CRL was approximately 3 in a hundred thousand for both receptors.

Non-Cancer Health Effects

In examining the potential for non-cancer health effects in risk assessments the Ministry calculates a hazard quotient. The Ministry has set a target HQ of 1.0 for all media and exposure routes combined. For each individual exposure route the target is 0.2. As with CRLs, when an HQ exceeds the target risk, mitigation and management measures are considered to reduce the risk below the target level.

In assessing the potential for non-cancer health effects, in this SL-HHRA, the same assumptions regarding receptor characteristics, exposure pathways, routes and frequency were used.

HQ's were calculated for acenaphthene, fluoranthene, naphthalene and pyrene at Station 5-10. These four were selected as the Ministry has derived toxicity reference values for chronic non-cancer effects from exposure to them and they were the PAHs for which some of the highest concentrations were reported at this Station. The highest calculated HQ was 0.00002 for the child exposed to pyrene, several orders of magnitude below the Ministry's target HQ. Since PAH concentrations were higher at the Drain HQ's were calculated for all seven PAH congeners (acenaphthene

acenaphthylene, anthracene, fluorene, fluoranthene, naphthalene and pyrene) for which the Ministry has derived chronic non-cancer toxicity reference values. The highest calculated HQ was 0.00007 for the child exposed to pyrene.

In humans many of the PAH congeners target similar organs for their health effects therefore the cumulative effects from exposure to a mixture of PAH congeners must be considered. This is done by summing the HQ's. The Ministry's target for a 'total HQ' is also 0.2 for each individual exposure route. The highest total HQ for the four PAHs assessed at Station 5-10 was for the child at 0.00004. The highest HQ at the Drain was also for the child at 0.0001. Again these are several orders of magnitude below the target. As a result of this large margin, for some of the PAHs with the highest concentrations, the Ministry is confident that all HQ's would be well below the target and therefore non-cancer health effects are not expected to be a concern at this site.

Conclusions

When a cancer risk is greater than one in a million the Ministry identifies that as a potential concern that needs to be further examined and risk management options are considered.

For the KAC for scenarios one to three, the total cancer risk levels were equal to or above the ministry's target. For the assumption of 5 events per year the total CRLs ranged from approximately 3 in a million to 2 in a hundred thousand, while for 12 events per year the total CRLs ranged from approximately 6 in a million to 6 in a hundred thousand. For scenario four for 5 events per year all routes of exposure and both total risks were below the Ministry's target level. For 12 events per year, for scenario four, risk from each individual route of exposure was below the Ministry's target level. However, the total risk was equivalent to the Ministry's target of one in a million.

From the data collected and exposure assumptions used in these calculations, it has been determined that the potential risk in a realistic exposure scenario in the KAC is equivalent to the Ministry's target risk level.

The total CRLs estimated for the Drain ranged from one to three in 100,000. Since these exceed the Ministry's target risk level of one additional cancer per million people, consideration may be given to risk management and mitigation measures. However, it should be noted that the estimation of risk at this location included all three samples analyzed from this location. Only one of these was a surface sample as a result this approach may have over estimated the risk. Further, exposure at this location would be as a result of trespassing on private property.

Table 3 Summary of Incremental Cancer Risk Levels for Kettle Creek Area of Concern and the Drain (Female)

Incremental Cancer Risk Levels					
	Scenario 1 KAC	Scenario 2 KAC	Scenario 3 KAC	Scenario 4 KAC	Scenario 5
Station ID	5-4 all B[a]P	5-4 $B[a]P_{Eqv}$*	5-10 $B[a]P_{Eqv}$*	Avg $B[a]P_{Eqv}$*	George Street Drain
5 events per year					
Ingestion	1×10^{-5}	1×10^{-6}	2×10^{-6}	below target	7×10^{-6}
Dermal	1×10^{-5}	2×10^{-6}	3×10^{-6}	below target	6×10^{-6}
Composite receptor (F)	2×10^{-5}	3×10^{-6}	6×10^{-6}	below target	1×10^{-5}
12 events per year					
Ingestion	2×10^{-5}	3×10^{-6}	6×10^{-6}	below target	2×10^{-5}
Dermal	3×10^{-5}	4×10^{-6}	8×10^{-6}	below target	1×10^{-5}
Composite receptor (F)	6×10^{-5}	8×10^{-6}	1×10^{-5}	1×10^{-6}	3×10^{-5}

*$B[a]P_{Eqv}$ stands for benzo[a]pyrene equivalents
F – represents the female receptor

Table 4 Summary of Incremental Cancer Risk Levels for Kettle Creek Area of Concern and the Drain

Incremental Cancer Risk Levels					
	Scenario 1 KAC	Scenario 2 KAC	Scenario 3 KAC	Scenario 4 KAC	Scenario 5
Station ID	5-4 all B[a]P	5-4 $B[a]P_{Eqv}$*	5-10 $B[a]P_{Eqv}$*	Avg $B[a]P_{Eqv}$*	George Street Drain
5 events per year					
Ingestion	1×10^{-5}	1×10^{-6}	2×10^{-6}	below target	7×10^{-6}
Dermal	1×10^{-5}	2×10^{-6}	3×10^{-6}	below target	5×10^{-6}
Composite receptor	2×10^{-5}	3×10^{-6}	5×10^{-6}	below target	1×10^{-5}
12 events per year					
Ingestion	2×10^{-5}	3×10^{-6}	5×10^{-6}	below target	2×10^{-5}
Dermal	3×10^{-5}	4×10^{-6}	8×10^{-6}	below target	1×10^{-5}
Composite receptor	6×10^{-5}	7×10^{-6}	1×10^{-5}	1×10^{-6}	3×10^{-5}

*$B[a]P_{Eqv}$ stands for benzo[a]pyrene equivalents

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